BioWires: DNA-Based Nanowires for Conductivity-Enhanced, Self-Assembling Nanoelectronics

Completed Technology Project (2014 - 2018)

Project Introduction

The BioWires project seeks to overcome two central issues identified in TA10-Nanotechnology: first, the miniaturization of nanoelectronics systems with features less than 10nm in size by 2025; and second the liberation of this technology from lithographic techniques for the minimization of upmass. Current technologies are unreliable at that scale and require exorbitantly heavy machinery to produce and maintain. This means that any unanticipated situations or failures encountered during a mission could not be addressed without large equipment, offsetting the impact of nanoscale systems. BioWires is an enabling technology, producing 2nm diameter wires in DNA that can self-assemble into advanced devices. In order to enhance the conductivity of nucleic acids to reach meaningful levels, a 1-atom thick chain of silver ions will be embedded into the core of the DNA strand. Because of the sequence specificity of DNA, these ions can be patterned in a variety of ways, ultimately allowing for advanced origami structures that mimic and ultimately replace nanoelectronic systems. These nanowire monomers can be synthesized by microorganisms at any point during a mission and self-assembled into devices without the burden of lithography and crippling upmass restrictions. This project has four phases. The first is to utilize a recent advance in single-molecule conductivity testing to bridge two carbon nanotubes with a DNA molecule. This process will take advantage of the hyprophillic interaction between PMMA and DNA by etching features onto silicon wafer to allow for specific placement of the molecules. This allows gold electrodes to be patterned at the ends of the tubes to generate molecule-specific data on electron transfer. Silver-embedded DNA will be assayed in this manner. The second phase will utilize this assembly and probing technique to assay a wide array of metalized nucleic acids by changing the metal, the pH, and the DNA structure. This will allow for the identification of the most conductive permutation and establish a basic monomeric toolkit for device assembly. The third phase will use the best system from the second phase to produce DNA origami structures in order to construct prototype nanoelectronic devices. The three target assemblies will be sheets, bundles and coils, allowing for microchip patterning, signal transduction and radio wave generation. These devices will provide a starting point for future manipulation of conductive biomolecular nanostructures. The final phase of the project will be to encode these DNA sequences back into microorganisms, specifically B. subtilis, a flight-tested microbe that is the target of current synthetic astrobiology research. This phase will employ techniques from synthetic biology and a modular system already created by the author to write the target one dimensional wires into the host DNA. Advanced origami structures can self-assemble from monomers produced by the bacterial chassis. This will reduce the upmass to a few spores that can be accessed at any point during a mission. Ultimately, this project will identify the ideal nucleic acid system for nanowire production at half an order of magnitude smaller than the TA10 target feature size. This will allow for the reliable, reproducible and scalable self-assembly of nanoelectronics from single components produced by a

BioWires: DNA-Based Nanowires for Conductivity-Enhanced, Self-Assembling Nanoelectronics

Table of Contents

BioWires: DNA-Based Nanowires for Conductivity-Enhanced, Self-Assembling Nanoelectronics

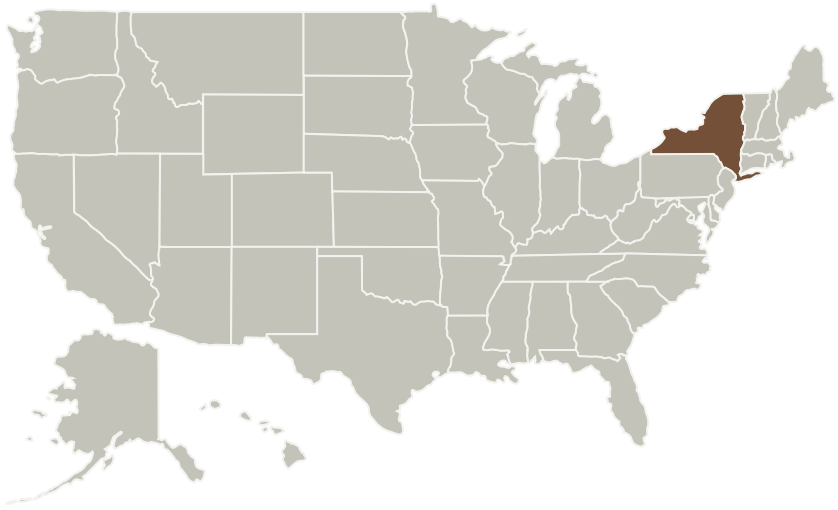
Completed Technology Project (2014 - 2018)

bacterial chassis, ultimately enabling minimal weight production and repair of a vast array of nanodevices on earth and in space.

Anticipated Benefits

Ultimately, this project will identify the ideal nucleic acid system for nanowire production at half an order of magnitude smaller than the TA10 target feature size. This will allow for the reliable, reproducible and scalable self-assembly of nanoelectronics from single components produced by a bacterial chassis, ultimately enabling minimal weight production and repair of a vast array of nanodevices on earth and in space.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Columbia University in the City of New York	Lead Organization	Academia	New York, New York

Primary U.S. Work Locations
New York

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Columbia University in the City of New York

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Shalom Wind

Co-Investigator:

Simon A Vecchioni

BioWires: DNA-Based Nanowires for Conductivity-Enhanced, Self-Assembling Nanoelectronics

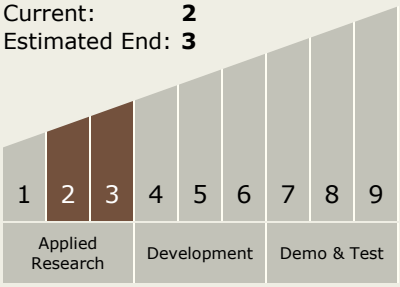
Completed Technology Project (2014 - 2018)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  - TX12.4 Manufacturing
    - TX12.4.1 Manufacturing Processes

Target Destination

Foundational Knowledge